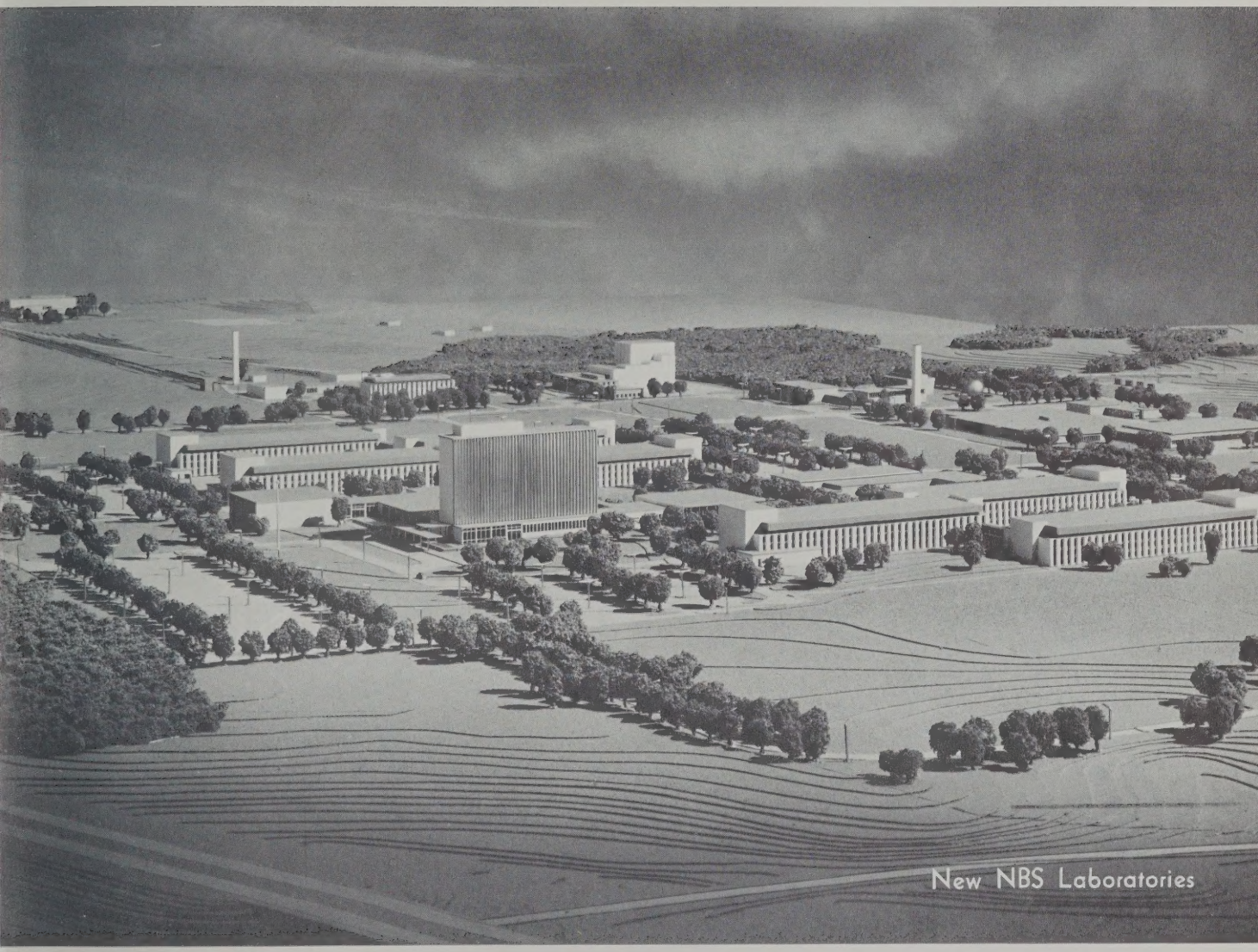
NATIONAL BUREAU OF STANDARDS

Technical News

BULLETIN



New NBS Laboratories

VOLUME 44 AUGUST 1960 NUMBER 8

NATIONAL BUREAU OF STANDARDS

Technical News

BULLETIN

U.S. DEPARTMENT OF COMMERCE
FREDERICK H. MUELLER, *Secretary*
NATIONAL BUREAU OF STANDARDS
A. V. ASTIN, *Director*

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COVER: Architect's model of the new National Bureau of Standards laboratories to be located at Gaithersburg, Md. Funds have been appropriated for the first phase of construction and the Bureau expects to break ground at the new site in the spring of 1961. An article describing the new laboratories begins on page 134.

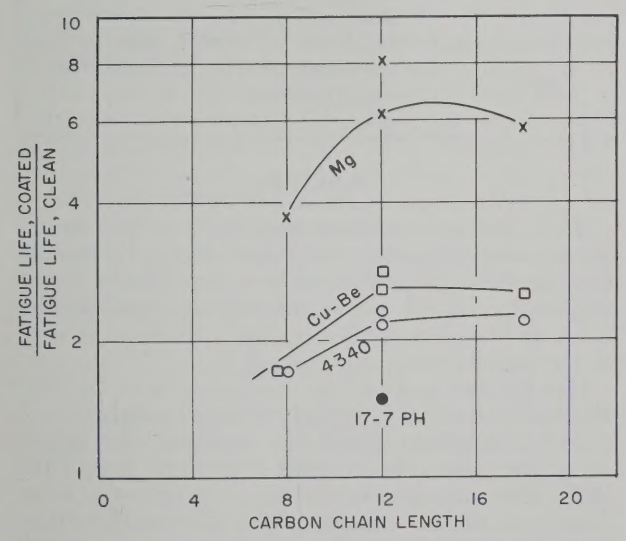
Effect of Organic Compounds on Metal Fatigue

THE BUREAU has recently investigated the effects of polar and nonpolar organic compounds on metal fatigue, in a program sponsored by the National Aeronautics and Space Administration. The experiments showed that coatings of long-chain polar substances greatly increase the fatigue strengths of steel, magnesium, and copper-beryllium alloys. On metal surfaces the polar compounds apparently form tightly packed monolayers that act as a barrier to water and oxygen molecules.[1] These results are expected to have practical application in extending the useful life of certain metals and alloys.

It is well known that environment influences metal fatigue. Even the mild corrosion that occurs when fatigue tests are run in a laboratory atmosphere may affect test results.[2] A number of studies have shown that certain types of organic compounds afford protection against corrosion under normal unstressed conditions.[3] Because these compounds readily lend themselves to mechanism studies, H. E. Frankel, J. A. Bennett, and W. L. Holshouser undertook the present investigation to ascertain their effect on fatigue behavior.

Cylindrical specimens were machined in which the longitudinal radius of curvature was held constant at 3.5 in. Minimum diameter of the reduced section was 0.310 in. for magnesium, and 0.250 in. for the other alloys. All of the experiments were conducted on rotating-beam fatigue testing machines of the R. R. Moore type, which apply pure bending moments to the test section. Specimens of six different alloys were tested to fracture under one of the following conditions: Cleaned and dry; coated with or immersed in an organic substance; immersed in water, either in the coated or uncoated condition.

Substance	Formula	Type
n-Hexadecane	$CH_3(CH_2)_{14}\,CH_3$	Nonpolar.
Xylene	$C_6H_4(CH_3)_2$	Do.
Benzene	C_6H_6	Do.
Octyl alcohol	$CH_3(CH_2)_6\,CH_2OH$	Polar.
Dodecyl alcohol	$CH_3(CH_2)_{11}\,OH$	Do.
Dodecylamine	$CH_3(CH_2)_{11}\,NH_2$	Do.
Octadecylamine	$CH_3(CH_2)_{17}\,NH_2$	Do.



Effect of polar organic compounds on the median fatigue life of four alloys: magnesium, copper-beryllium, 4340 steel, and 17-7 PH stainless steel. For the first three materials, the upper value at a chain length of 12 represents dodecyl alcohol, the lower value, dodecyl amine.

The water and nonpolar liquids either had no significant effect or caused a decrease in the fatigue life of the specimens. The polar organic compounds, however, caused an increase of over 600 percent in the fatigue life of the magnesium alloy, stressed at 12,500 psi; an increase of approximately 250 percent in the copper-beryllium alloy, stressed at 50,000 psi; and an increase of approximately 200 percent in the steel alloy, stressed at 100,000 psi. These compounds had little, if any, beneficial effect on the other three alloys, titanium, aluminum, and stainless steel, probably because of the strongly adherent oxide films that form on these materials.

The results showed no appreciable difference between the specimens that were immersed in the polar substances and those that were merely coated with them. Coating the specimens with one of the substances, dodecyl alcohol, and then testing in a tap water environment resulted in as much improvement as had been obtained with specimens tested in air.

Compounds having chain lengths of 8, 12, and 18 carbon atoms were compared. Of these substances, those having 12-carbon chains apparently gave optimum conditions. The comparison also showed that the type of polar group does not appear to be as important as the number of carbon atoms in each molecule.

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[1] *For further technical details, see* The effect of oleophobic films on metal fatigue, *by H. E. Frankel, J. A. Bennett, and W. L. Holshouser, J. Research NBS*, **64C**, *147 (1960)*.

[2] Some further experiments on atmospheric action in fatigue, *by H. J. Gough and D. G. Sopwith, J. Inst. of Metals*, **56**, *55 (1935)*.

[3] Hydrophobic monolayers adsorbed from aqueous solutions, *by E. G. Shafrin and W. A. Zisman, J. Colloid Sci.* **4**, *571 (1949)*.

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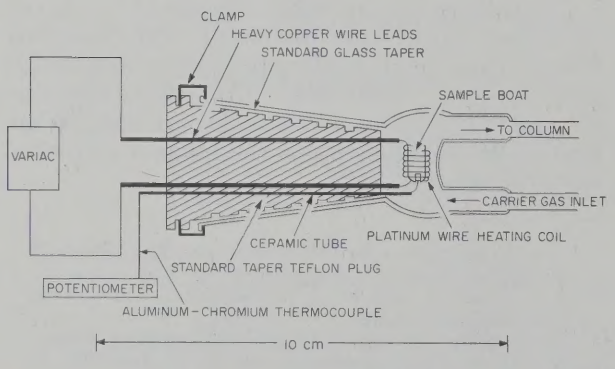
Gas Chromatography for Analyzing Copolymer Systems

A RAPID, vapor-phase chromatographic method [1] for identifying acrylic polymers and copolymers as well as other resins has been developed by the Bureau. With this approach, polymers can easily be characterized and as little as 0.2 percent copolymer can be detected. Acrylic copolymer composition can be quantitatively determined within ±0.5 percent. The analysis requires relatively inexpensive equipment, needs only a small amount of material, and is readily adaptable for different copolymer systems.

Acrylic polymers and copolymers find many industrial applications as transparent plastic sheets, molding materials, and resinous coatings, as well as in prosthetic dental materials. Methyl methacrylate—often crosslinked with other materials such as ethylene dimethacrylate to modify its properties—is the main constituent of denture base resins, plastic teeth, and anterior plastic fillings.

Previously the detection and quantitative determination of copolymeric constituents in acrylic polymers had been difficult. Often the composition of crosslinked, insoluble polymers could not be determined with any degree of accuracy. However, with the gas chromatographic procedure developed by G. M. Brauer, J. Strassburger, F. Lehmann, and coworkers in the dental research laboratory, such materials are easily analyzed. From the study of the degradation products of the polymers and copolymers used, information on mechanisms of breakdown and on the structure and composition of materials can be obtained.



Sample pyrolysis chamber. By degrading the polymer mixtures or copolymers directly in the gas stream of the chromatograph, all the products can be carried immediately into the chromatographic column for analysis.

Gas Chromatography

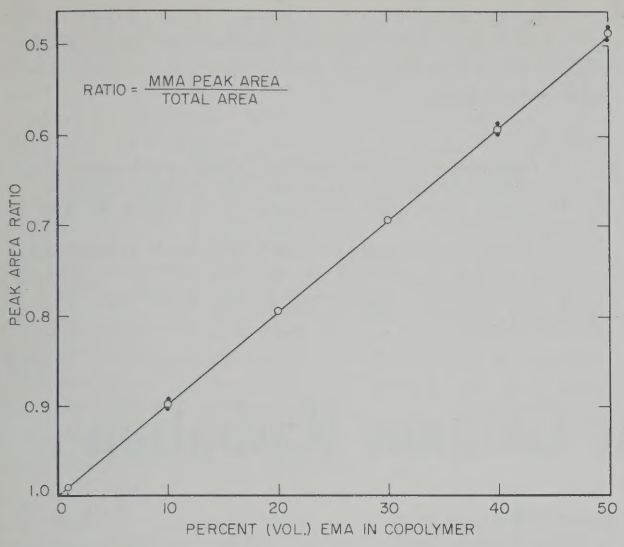
In gas-chromatographic separation the mixture under study is passed through a column containing a stationary phase, which consists of either a solid adsorbing-agent or a liquid partitioning-agent. Because of the selective retardation exerted by this stationary phase, the components of the mixture, carried by a mobile gas, move through the column at different effective rates, depending on their individual affinities to the stationary phase. As a result, the components are separated so that the products that are retained least emerge from the column first.

The detecting system used in this work is based on measurement of thermal conductivity. When a constant flow of gas passes over a fine wire heated by an electric current, the rate of heat loss by the wire is constant. A change in composition of the gas stream will cause a change in heat loss and thus a change in resistance. These changes are amplified and recorded as a series of peaks on a chart. The peak height and/or peak area on this plot is proportional to the quantity of a component and affords a very simple and rapid method of quantitative analysis. Under a definite set of operational conditions, the retention time, i.e., time at which the peak appears on the chromatograph, is characteristic of a certain component.

Analysis

The Bureau's method employs a commercial chromatograph with a stainless steel column containing dinonyl phthalate or other liquids as the stationary liquid phase coated on ground fire brick as the inert, solid support. Helium is used as the mobile gas.

Qualitative analysis of polymers can be conducted by analyzing liquid pyrolysis products. A 2- to 3-g sample is placed in a small still pot, which is a glass test tube having a ground-glass ball-joint that can be connected to a delivery tube. The still pot is enclosed in a temperature-controlled air jacket. The temperature is raised rapidly to 350 °C and the pyrolyzate led into a test tube immersed in an ice bath. The pyrolysis condensates are stored in a refrigerator prior to the chromatographic analysis.



Plot of peak-area ratio versus percent composition for a methyl methacrylateethyl methacrylate copolymer.

This technique is not suitable for quantitative analysis because loss of some volatile constituents may occur, even though the delivery tube is cooled in an ice bath. Also, changes in the multicomponent reaction mixture may take place in the interval between degradation and analysis.

In the quantitative analysis, to keep the experimental conditions as constant as possible, the polymer is degraded on a hot wire coil or in a small pyrolysis boat set in the gas stream of the chromatograph. This enables the helium gas, passing over the filament on which the sample is placed, to carry the vaporized components of the sample directly into the chromatographic column. The ends of the coil are connected to a variable transformer by which the coil temperature can be maintained at about 400 °C.

In this temperature range, the only depolymerization product of the poly(methyl methacrylate) degradation is its monomer, even when other copolymeric constituents are present. Hence, the chromatograms of all methyl methacrylate copolymers will have a large peak due to this component and a number of smaller peaks which are caused by the other constituents.

Identification

Chromatograms of the pyrolyzates can be used to identify polymers by comparison of their peaks with those obtained from polymers of known composition. Copolymeric constituents of as little as 0.1 percent can be detected. Chromatograms of the pyrolysis products of mechanical polymer mixtures and the corresponding homogeneous copolymers are not identical. Although similar degradation products are formed, their quantities are different. Thus it is possible to distinguish between copolymers and polymer mixtures of the same composition.

In all of the chromatograms a few sharp, characteristic peaks of reproducible height are present. The most prominent peaks, representing methyl methacrylate and the other component of the mixture, are chosen to determine the peak-area ratios. A calibration curve—of known polymer composition versus peak-area ratios—is used to determine the quantitative composition of unknown polymer mixtures or copolymers.

By this method, the copolymer composition can usually be determined within a precision of 0.5 percent. For the analysis of methyl methacrylate-ethyl methacrylate copolymers, the standard deviation of single measurements is approximately 0.48 percent over the entire composition range measured. If triplicate measurements are averaged, the "true" value can be predicted with 95 percent confidence within ±0.55 percent of the average.

Higher Temperatures

Recent studies [2] at higher temperatures have shown that the method is applicable for determining the quantitative composition of pyrolysis products as well as for identifying the original composition of the materials. In these studies, poly(methyl methacrylate) and polystyrene were decomposed at temperatures ranging from 400 to 1,100 °C. The pyrolysis chamber was modified to include a small high-silicon glass boat surrounded by a platinum heating coil placed inside the chromatograph. With this boat, the sample can be weighed both before and after heating and the residue can be conveniently measured. The apparatus is so designed that the degradation tempera-

Analyzing acrylic copolymers and polymers by gas chromatography. As little as 0.2 percent copolymer can be detected by this qualitative and quantitative method. G. M. Brauer inserts specimen into chromatographic column prior to degradation.

ture can be measured by a thermocouple set in an indentation at the bottom of the boat.

Identity of products was established from their retention times and the quantity of each compound from the peak areas on the chromatograms. Analysis could usually be accomplished with a reproducibility of better than ±1 percent.

The quantitative analysis of the pyrolyzate obtained by this technique makes it possible to evaluate the primary and secondary reactions taking place during the degradation reaction and aids in studying the mechanism of depolymerization over wide temperature ranges. The process also gives valuable information about the thermal stability of polymers and the structure of polymers and copolymers.

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[1] Analysis of methyl methacrylate copolymers by gas chromatography, *G. M. Brauer, J. Strassburger, M. Tryon, and A. F. Forziati, Anal. Chem.* **32**, *454 (1960).*

[2] Pyrolysis products of acrylic resins, *F. Lehmann, A. F. Forziati, and G. M. Brauer, Abstract, 38th meeting, International Association for Dental Research, Chicago, March 1960, p. 93.*

Calculation of Fallout Gamma Radiation Within Structures

A METHOD for calculating fallout gamma radiation intensities within structures has been developed by C. Eisenhauer and L. V. Spencer of the Bureau working under the sponsorship of the Office of Civil and Defense Mobilization. The method makes possible simple calculations of intensities within basements, and it can be used to find, at the center of a structure, the intensity of radiation entering through windows. With further refinement, it should provide an improved theoretical approach to the analysis of shielding properties of structures.

In general, for a simple structure, fallout radiation particles will be distributed uniformly over the roof of the structure and on the ground surrounding it. The radiation that reaches a detector inside can then be separated into that part coming through the walls and that coming through the roof. The intensity, or dose rate, of gamma radiation within the structure will depend mainly upon barrier attenuation (a function of barrier thickness and density) and geometrical attenuation (a function of the solid angle subtended at the detector by the barrier).

The geometrical attenuation from sources on the roof can be described in terms of a single geometry factor. The dose rate from roof sources is then equal to the product of the barrier factor (barrier attenuation) and the geometry factor.

The geometrical attenuation of radiation from sources on the ground is somewhat more complicated because the direct radiation behaves differently from the radiation that has been scattered in the walls. The direct radiation reaches the detector only from below, while scattered radiation may reach it from either above or below. In the present method, the geometry factor for radiation from the walls is therefore separated into a direct and a scattered component. The geometry factor for direct radiation has long been understood. Although the exact value of the

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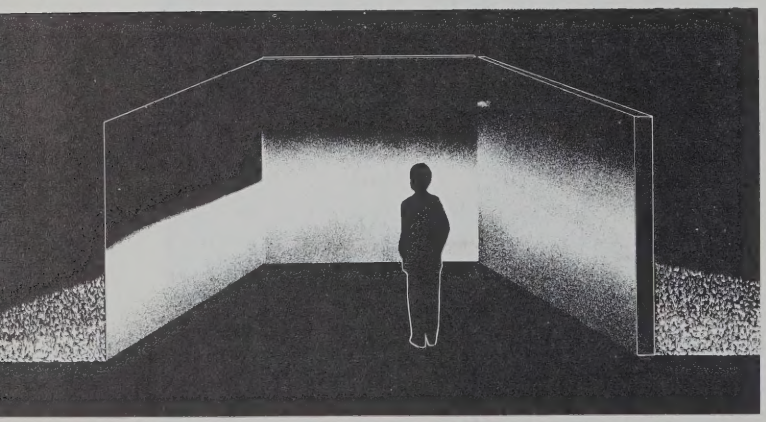


This drawing illustrates how the distribution of radiation from fallout varies for walls of different thicknesses by showing how the radiation would look if it were visible to the eye. The radiation emerging from the thin wall on the left is the most intense. It is composed almost entirely of direct radiation from the radioactive sources on the ground outside. Consequently, almost all such radiation appears to emerge from the walls at points below eye level. The radiation emerging from the thick wall on the right is the least intense. Being composed almost entirely of radiation scattered at least once in the wall, it appears as a diffuse glow from points both above and below the eye. The radiation emerging from the walls of intermediate thickness (about 3 in. of concrete) in the center is intermediate in intensity and distribution. The contrast in overall intensity between the thickest and thinnest walls would be much greater than shown here.

geometry factor for the scattered radiation has not yet been calculated, it is known to lie within certain limits and to vary slightly with wall thickness. A suitable value may therefore be estimated. It is also known that the radiation emerging from very thin walls is almost entirely direct radiation, while that emerging from very thick walls consists almost entirely of scattered radiation. For very thin walls, then, the dose rate is obtained as the barrier factor times the geometry factor for the direct radiation; while for very thick walls, the dose rate equals the barrier factor times the geometry factor for scattered radiation. For walls of intermediate thickness, the dose rate is obtained as the sum of the two products, each weighted according to the relative amounts of scattered and direct radiation.

Although several experiments have been performed to measure dose rates inside structures surrounded by artificially radioactive sources, the results of these experiments do not provide a proper test of calculations made by the Bureau's method because of complicating factors such as the presence of floors and inner partitions in the building. However, data suitable for comparison were obtained from a controlled experiment made at the Army Chemical Warfare Laboratories using cobalt-60 sources distributed around a concrete blockhouse. The blockhouse is 12 ft long, 12 ft wide, and 8 ft high. Data were taken at ground level, 3 ft above ground, and 6 ft above ground at the center of the structure for wall thicknesses of 4 and 8 in. of concrete. Although the data are somewhat limited, they verify the trends predicted by the calculations.

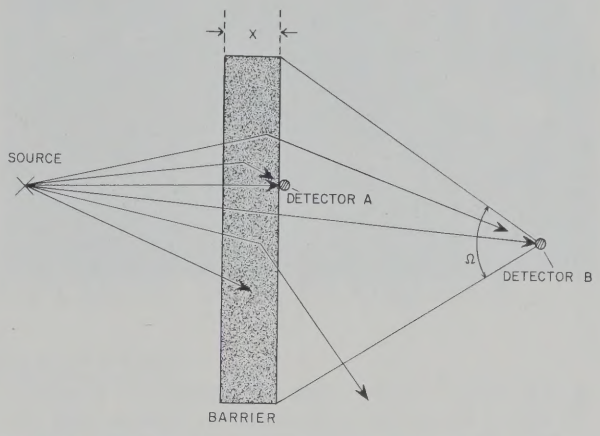


Diagram showing how intensity of radiation received at a detector depends on barrier attenuation and geometrical attenuation. Radiation not absorbed in the barrier can reach the detector either directly from the source or after one or more scatterings in the barrier. The intensity at detector A, adjacent to the barrier, due to the fixed source on the left depends primarily on barrier thickness x. The dose rate at detector B, however, depends not only on barrier thickness but also on the solid angle subtended at the detector by the barrier. The geometrical attenuation is described in terms of this solid angle.

NEW MOTION PICTURE RELEASED

Trapping of Free Radicals at Low Temperatures presents a study of one of the most powerful sources of chemical energy yet discovered—the elusive, highly reactive molecular fragments known as free radicals. Free radicals take part in almost every chemical reaction, and are especially important in high-temperature reactions—rocket flames and stellar atmospheres, for instance.

The picture begins by explaining the theory of free radicals and describing something of their behavior. The remainder of the film shows in detail the performance of an experiment in the trapping and storing of the free radicals at temperatures within a few degrees of absolute zero by a special process developed at the Bureau.

Among the interesting features of the film are the sequences showing the handling of liquid helium—the coldest liquid known to man. Also, there are brilliant color views of the glows and flashes emanating from free radicals trapped in a solid matrix of frozen gas. The various colors produced by varying the composition of the gas are shown and discussed.

The free radicals are produced in an electric discharge. Under ordinary circumstances, they would immediately recombine to form molecules again, but when trapped in the frozen matrix, they remain long enough to be studied by spectroscopy, electron spin resonance, and many other techniques. One of the most interesting and significant properties of free radicals is their ability to release vast amounts of energy when they recombine.

The special National Bureau of Standards program of free radical research, from which this film arose, was conducted under the sponsorship of the Department of Defense.

Trapping of Free Radicals at Low Temperatures, a 16-mm sound, color film, running time 13½ min, is designed for high school and college science classes, and scientific, technical, industrial, and civic groups. It is available for loan or sale from the Office of Technical Information, National Bureau of Standards, Washington 25, D.C. The current purchase price is $54.64 f.o.b. and is subject to change without notice. The film may be borrowed free of charge, except for return postage and insurance charges.

SPECTRORADIOMETER for FLUORESCENT LAMPS

W. L. Holford monitors the current and voltage supplied to a fluorescent test lamp and an incandescent standard lamp while newly constructed spectroradiometer records relative spectral irradiance data. The incandescent lamp is located behind a shield.

A NUMBER of methods are available for evaluating the color of fluorescent lamps, and for studying the effects of the many variables in their manufacture. However, the expanding applications of fluorescent illumination today show that when these lamps are supplied by different manufacturers it is not always possible to achieve a perfect color match. The Bureau has therefore constructed a spectroradiometer to calibrate fluorescent lamp color standards that may be used throughout the industry to obtain color uniformity.[1] Measurements made with this instrument will also form a basis for international comparisons of fluorescent lamp colors.

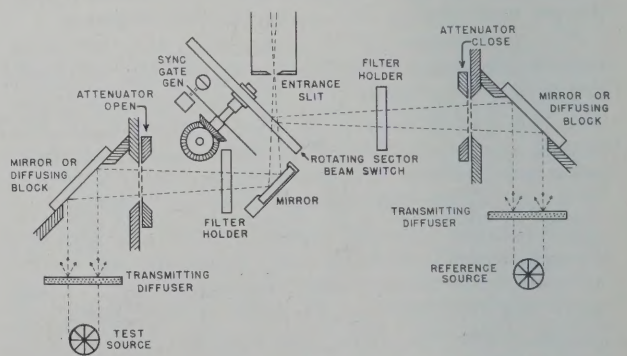
Spectroradiometers generally have three basic components: An element for dispersing radiant flux from a light source into a spectrum, a radiometric detector for measuring this flux in each wavelength, and a recording device for plotting the resulting spectral irradiance data. From these data the color of the source is determined. Some spectroradiometers [2] measure the current from the detector to find the spectral irradiance of fluorescent lamps. In the present work, however, a method was desired that would be essentially independent of both the response characteristics of the detector and the spectral transmittance of the dispersing element. A system was therefore designed by H. K. Hammond, W. L. Holford, and M. L. Kuder in which a test lamp is compared directly with an incandescent lamp of known color temperature.

A double-prism monochromator with a cam-linearized wavelength drive from 360 to 760mμ is used as the dispersing element in the instrument. The detector is a multiplier phototube with high spectral sensitivity throughout the visible spectrum. A 10-in. strip-chart recorder is used to plot the relative spectral irradiance ratio of the two light sources. These three components, together with the power supplies and electronic circuitry, are housed in a console. The two light sources are mounted on the outside of the console at adjacent entrance ports.

Optical attenuators, in the form of adjustable apertures, are located in the path of each light beam. Each attenuator has two identical components, one fixed and one movable. Each component is a flat metal foil with an array of 25 diamond-shaped holes, $\frac{1}{10}$ in. on a side. The two components of an attenuator are fitted together in such a way that they slide over each other to enlarge or decrease the size of the holes as required.

In operation, the spectroradiometer compares the radiant flux from each source as the spectrum is scanned. When the intensities of the two beams are unequal, the unequal phototube signals cause a servomotor to adjust the attenuators, simultaneously opening one and closing the other, until the beam intensities are equal. The attenuation required at each wavelength for equalization is automatically plotted as a function of wavelength over the visible spectrum. The curve thus recorded is the ratio of relative spectral irradiance from the two sources.

Wavelength correlation between monochromator and recorder is maintained by driving the prisms and the strip chart with a second motor. The speed of this motor is varied according to the magnitude of the unbalanced signal. When the



Entrant beam geometry of the spectroradiometer. In this system, the light beams from a fluorescent test lamp and an incandescent standard lamp are optically attenuated to equalize the intensities of the two beams as the spectrum is scanned.

curve is flat, the rate of scan is maximum; when the curve becomes steep, the rate of scan is automatically reduced to assure faithful recording of the peaks of sharp spectral lines. Auxiliary gears and clutches provide wavelength scales of either 1mμ or 10mμ for each inch of chart length. At the latter rate, the time required for scanning the visible spectrum is about 8 min.

Although the spectroradiometer was built primarily for the calibration of fluorescent lamps, it can also measure the relative spectral irradiance of any source or source-filter combination. Luminescent or fluorescent materials can be measured if they have several square inches of uniform luminance and if the luminance is at least 1 foot-lambert.

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[1] *For further technical details, see* Ratio-recording spectroradiometer, *by H. K. Hammond, W. L. Holford, and M. L. Kuder, J. Research NBS* **64C**, *151 (1960).*

[2] An automatic recording spectroradiometer, *by V. K. Zworykin, J. Opt. Soc. Am.* **29**, *84 (1939)*; and Spectroradiometry, *by F. J. Studer and W. R. Jacobsen, GE Review* **52**, *No. 10 (1949).*

45th National Conference on Weights and Measures

THE HIGHLIGHT of the 45th National Conference on Weights and Measures (June 6–10) was the presentation by Secretary of Commerce Frederick H. Mueller of a set of measurement standards to the new State of Hawaii. The ceremony was held June 8 in the Department of Commerce Auditorium, and was included as a formal session of the Conference. These state standards, which are based on the national standards, provide the basis for an accurate, uniform, consistent measurement system important to the commerce and industry of Hawaii.

The set of standards presented included a yard bar and a 100-foot measuring tape representing length. Capacity standards ranged from 5 gallons down through 1 gallon, ½ gallon, 1 quart, 1 pint, ½ pint, 1 gill, and 2 fluid ounces. The mass standards of specially designed Nichrome ranged from 30 pounds down to one millionth of a pound, avoirdupois weight. The standards were accepted for Hawaii by the senior senator from Hawaii, the Honorable Hiram L. Fong, and by Sanford L. Platt, Vice President of the Hawaiian Pineapple Growers Association and special representative of Gov. William F. Quinn of Hawaii. Congressman Daniel K. Inouye of Hawaii was also an honored guest.

Secretary Mueller also delivered the Weights and Measures Conference keynote address on June 7 where he cited the National Conference on Weights and Measures as an excellent example of cooperation between the Federal Government and State and local governments. He emphasized that an effective weights and measures program provides a sound measurement foundation which helps all business, large and small, buyer and seller.

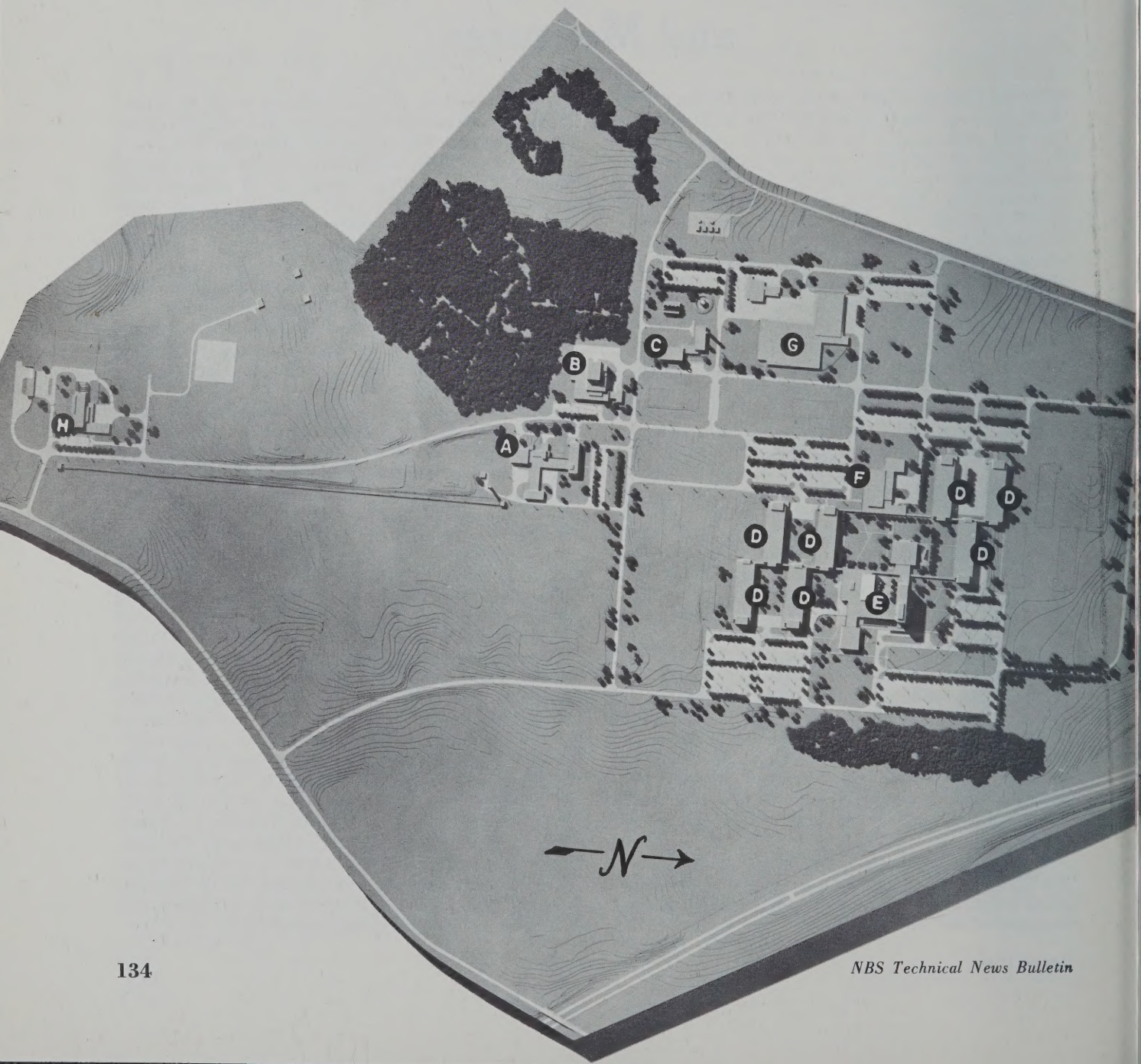
He was followed on the program by Dr. A. V. Astin, NBS Director, who reviewed recent technical achievements of the Bureau in the field of measurement.

Other speakers at this session were H. E. Crawford, Conference Chairman and Inspector of Weights and Measures, Jacksonville, Fla., and the Honorable D. N. McDowell, Director, Department of Agriculture, State of Wisconsin, and representing the National Association of State Departments of Agriculture. The balance of the program was devoted to the presentation of committee reports and technical papers on such diversified subjects as *State Mass Standards*, *the Banana Market*, *Testing Aerosol Containers*, *Inspection*, *Packaging*, *and Labeling of Poultry Products*, and *New Developments in Testing Equipment.* Total registration was over 400 with 36 states represented.

The conference, which was organized in 1905, is sponsored by the National Bureau of Standards and brings together weights and measures officials, as well as representatives of business and industry. Model laws, specifications, tolerances, regulations, and enforcement practices are recommended by the conference for adoption by the various states, which have the legal responsibility of regulating commercial weighing and measuring devices, and of controlling commercial transactions involving quantity. The Bureau, through its Office of Weights and Measures, cooperates with the States in this endeavor by providing reference standards, calibration service, and a wide range of technical advisory programs. Thus, the national standards of length and mass, which are in the custody of the Bureau, are translated into everyday use.

Officers elected for the ensuing year are: Rollin E. Meek of Indiana, Chairman; J. W. D. Harvey of Georgia, Harlan D. Robinson of Maine, A. D. Rose of California, and J. D. Walton of Texas, Vice Chairmen; and C. C. Morgan of Indiana, Treasurer. Dr. A. V. Astin will continue as President of the Conference and W. S. Bussey, Chief of the Office of Weights and Measures, will continue as Secretary, both *ex officio.*

Construction of New NBS Laboratories To Begin Next Spring

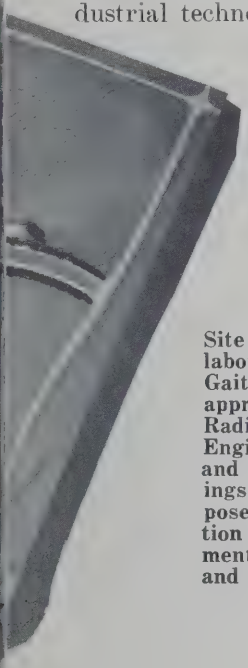


WITHIN the next 12 months, the Bureau will break ground at its new site 20 miles from Washington, D.C., at Gaithersburg, Md., and start construction of the first three buildings in its new facilities.[1] Planning for the new laboratories has been underway since the summer of 1958, when Congress appropriated funds for architectural work. The Public Buildings Service of the General Services Administration, which is responsible for the construction program, expects to award the first contracts toward the end of 1960.

The two laboratory buildings to be started in the coming year (Engineering Mechanics and Radiation Physics) are being given priority because of the urgent need for expansion of these research programs. This expansion involves the installation of large equipment in specially designed structures. Funds for these laboratories, the scientific equipment, the site development, and the Power Plant which will serve the entire new facility, were made available July 1, 1960 in a Congressional appropriation of $23.5 million.

When completed, the new "campus" will have 20 buildings housing new research facilities as well as all of the Bureau's present programs. The total cost of the new laboratories, new equipment and moving of present equipment, is expected to be about $104 million. Design of the new facilities is by the architectural firm of Voorhees Walker Smith Smith and Haines of New York City.

For several years now, the Bureau's vital services to national defense, military research, and industrial technology have been greatly hampered by inadequate and outmoded research facilities. Many of the buildings on the present site are temporary, and even the permanent buildings are outmoded. Renovation and modernization would be costly, amounting to more than half the estimated cost of a complete new facility. In addition, some of the facilities contemplated could not be built in an urban site such as the Bureau's present location in Washington. Space for further expansion is also lacking on the present site.



Site plan of the Bureau's new laboratories to be located near Gaithersburg, Md. Funds have been appropriated for construction of (A) Radiation Physics Laboratory, (B) Engineering Mechanics Laboratory, and (C) Power Plant. Other buildings planned are (D) general purpose laboratories, (E) Administration Building complex, (F) instrument shops, (G) supplies and plant, and (H) Fire Research Laboratory.

As a result of the rapid expansion of technology and the growth of scientific research, the Bureau's responsibilities have greatly increased. Extensive programs of research and development must now be conducted in the physical sciences and engineering to meet the needs of science and industry for new and improved standards and measurement methods. The new site will enable the Bureau to plan and conduct a more up-to-date program consistent with its increasing responsibilities.

The rural location will remove the Bureau's work from the variety of mechanical, electrical, and atmospheric disturbances present in a city and will reduce the effect of these factors on precise scientific measurements. In addition, the new site will provide a rural location where scientific programs can be undertaken with a minimum of interference to community life.

A tract of approximately 550 acres of land near Gaithersburg, Md., was acquired 4 years ago. The new site was selected after careful consideration as being suited to the special requirements of the Bureau's scientific and engineering programs. The choice was based upon a number of factors, including accessibility to roads and topography required for certain projects.

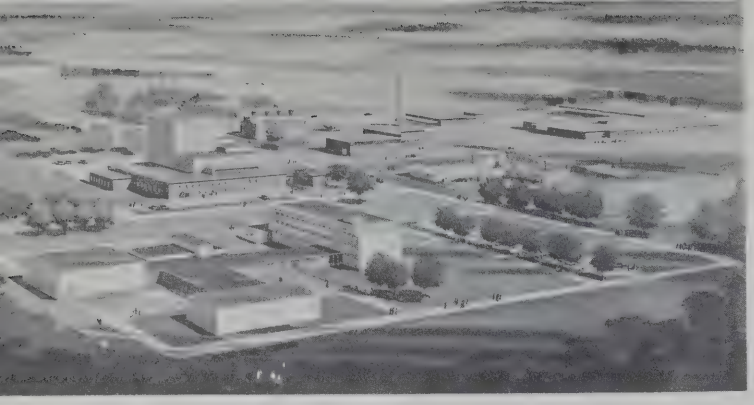
Completion of the Engineering Mechanics Laboratory and the Power Plant is expected in the fall or winter of 1962. The Radiation Physics Laboratory is scheduled for completion in the spring of 1963.

The first buildings are described in the following paragraphs and an outline is given of the remainder of the facilities which are planned for construction as additional funds become available.

Engineering Mechanics Laboratory

The Engineering Mechanics Laboratory is a specially designed building which will house large capacity compression and tension machines, dead weight machines, offices, and general service space. These new calibration facilities for force-measuring devices are urgently needed in missile and rocket development programs to supply the accurate determination of the rocket thrust and of missile load which are so critical at the early launching stages of a missile flight. The facilities will also be of great value to other industries.

A new compression and tension testing machine of at least 10,000,000-lb capacity which requires a working height of 80 ft will be located in the



Architect's rendering of first phase of construction at new NBS site, Gaithersburg, Md. In addition to site preparation and installation of utilities, the first phase will include construction of a Radiation Physics Laboratory (foreground), Engineering Mechanics Laboratory (left rear), and Power Plant (rear center).

largest area in the laboratory. This will be a replacement for the Bureau's present 50-year-old machine which provides compression measurements only. An area of 2,500 ft^2 with a 20-ft clear height is being prepared for the horizontal testing machine which is capable of 2,300,000 lb in compression and 1,150,000 lb in tension.

Final designs are being completed on dead weight machines of 300,000- and 1,000,000-lb capacity which will also be located in this building.[2] The Bureau will then be able to calibrate force measuring devices up to 1,000,000 lb by applying test loads accurate to 0.005 percent. Present dead weight machines extend only to 111,000 lb, making it impossible to achieve high accuracy when calibrating very large devices.

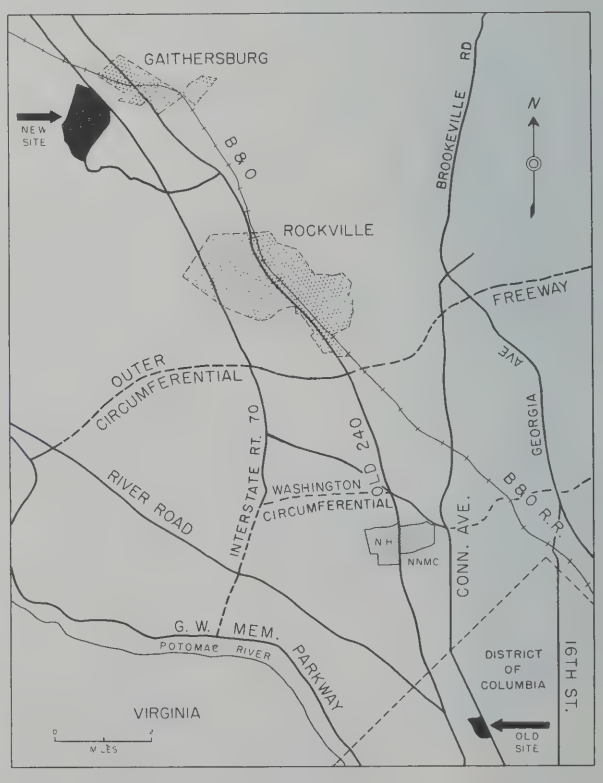
Radiation Physics Laboratory

The Radiation Physics Laboratory will be a unique and complex structure with a gross area of approximately 155,000 ft^2 in four levels below grade and three above. The building will house the Radiation Physics Division with its extensive programs in neutron physics, radiation theory, radioactivity, X-rays, high-energy radiation, nucleonic instrumentation, and radiological equipment.

This laboratory will also house the high-intensity electron accelerator now being designed for the Bureau.[3] This linear accelerator will produce one of the world's most intense high-energy electron beams—a beam with energies continuously variable from 10 to 100 Mev and power outputs on the order of 40 kw. This power output is about 100,000 times that now obtained in this energy range at the Bureau.

The linear accelerator (Linac) will be placed in a narrow room 140 ft long with a magnet room at the end and three measurment rooms located radially around the magnet room. The electron beam from the Linac will be controlled by the magnets and deflected into one of the three measurement rooms. Shielding for the magnet room is provided by 12-ft thick concrete walls and interlocking concrete doors. The other rooms will not require elaborate shielding since they are peripheral rooms 40 ft underground. Each of the measurement rooms and the magnet room require 10-ton or 20-ton cranes to manipulate equipment and shielding blocks.

The sub-basement level, the lowest level of the main part of the building, will contain the Linac complex, maintenance and experimental set-up laboratories for the Linac, several X-ray research laboratories, a cobalt-60 source pool, and 1,000 curie sources of cobalt-60 and cesium-137. The basement level will house the Bureau's 50-Mev betatron, 180-Mev synchrotron, 3-Mev and 1.5-Mev electron accelerators, and the 2-Mev Van de Graaff positive ion accelerator. Space is planned on this floor for a variable energy, 40-Mev cyclotron, to be acquired at a later date. The first floor will contain the upper level of the betatron, synchrotron, and cyclotron rooms, as well as other laboratories and offices. A three-story general purpose wing at the opposite end of the building from the accelerators will contain offices, conference rooms, and some laboratories.



The new Bureau site near Gaithersburg, Md., is shown at upper left. At lower right is the present site within the District of Columbia. On U.S. Route 240 are the National Institutes of Health (NIH) and the National Naval Medical Center (NNMC). Dotted lines indicate highways proposed or under construction.

Also included in the structural features of the building are provisions to permit its use as a fallout shelter for approximately 1,500 persons.

The size and topography of the new site make it possible to have four Time of Flight Tubes—100, 200, 300, and 800 m in length—in connection with the Radiation Facility. The Time of Flight Tubes would be used to measure neutron cross sections and to measure the energy spectra of photo neutrons.

The 1.4-Mev transformer-rectifier accelerator now being used at the present site will be replaced by a 3-Mev electron accelerator and a 1½-Mev electron accelerator, mentioned above. Other new facilities to be installed in the building include beam pulsing equipment for NBS's 2-Mev positive-ion Van de Graaff accelerator, a precision beta-ray spectrometer, four multichannel pulse height analyzers, and a gamma ray source and container. A 500-kv X-ray set will be moved from the present site, together with a number of X-ray sets of 250-kv and lower energy.

Flexible Laboratory Buildings

More than half the total laboratory space is designed for multipurpose use to meet the general requirements of physics, chemistry, and engineering research. There will be seven general purpose laboratories containing a total of 556,000 ft^2. Funds for these laboratories have not yet been provided.

The basic building plan is rectangular, composed of three floors containing 112 laboratory modules on each floor—60 large modules back to back in the center of the building and 52 small modules on the perimeter. The size of the large modules is 11 by 24 ft; the small ones are 11 by 16 ft. Movable steel partitions will be installed to subdivide laboratory areas. A room may be a single 11-ft module or multiples of 11 ft, depending on the requirements of the work. Laboratory services are available at service enclosures every 11 ft and will be distributed into the laboratory as required along the partitions or in floor trenches.

The research programs have been arranged so that scientists and engineers having mutual interests are located near each other and may share specialized equipment. Enclosed passageways connect the general purpose laboratory buildings at all floors.

A number of special purpose laboratories and areas are being planned for work having very unusual requirements. These programs include fire research, sound chambers, high-pressure facilities, and other such programs.

Administrative and Supporting Facilities

The administration building complex is centrally located. It includes a library with separate study rooms as well as reading rooms and open stack areas; a museum; two auditoriums, one seating 750 people and the other 300; lecture rooms and classrooms for NBS Graduate School courses and scientific meetings; and a cafeteria with a few small dining rooms. On the basement floor are office services and a photographic laboratory with a television-motion picture studio. The Applied Mathematics Laboratories and computer facilities are also in this building, with direct signal connections from other laboratories for input of experimental data to the computer. Administrative offices of the Bureau will be in an 11-story section of the building complex, the highest structure on the site. Funds for this complex have not yet been provided.

Instrument shops are located near the central complex, connected by glassed-in passageways from the general purpose laboratory buildings. Supply, maintenance, and warehousing facilities have a separate building.

Nuclear Reactor Plans

The Bureau's 1961 appropriation includes funds for detailed engineering design on a nuclear research reactor and associated facilities. A tentative location on the site has been selected for the reactor, which will serve not only the Bureau but other physical and life science laboratories in the Washington area as well. Many programs will be made possible by the reactor, including the Bureau's traditional activities in the fields of science and technology—supplying precision measurements, improved instrumentation, and precise data for basic science and engineering.

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[1] NBS to be relocated, *NBS Tech. News Bull.* **40**, 135 (1956).

[2] Million-pound dead-weight machine designed, *NBS Tech. News Bull.* **43**, 240 (1959).

[3] High-intensity electron accelerator for new NBS site, *NBS Tech. News Bull.* **44**, 73 (1960).

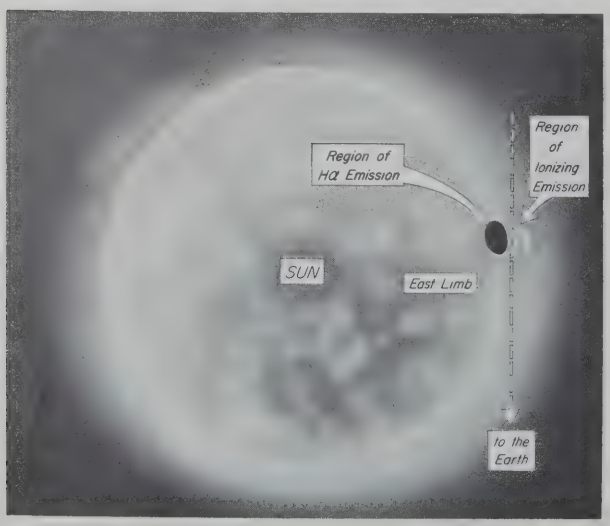
Architect's rendering of the Engineering Mechanics Laboratory, one of the three building units included in the first construction phase for the new Bureau laboratories.

Unusual Solar Disturbance

MEMBERS of the solar research group of the Radio Warning Services Section of the Bureau's Boulder (Colo.) Laboratories have been appraising an unusual solar event which occurred on June 9, 1959. A severe radio blackout of very long duration, and large radio noise outbursts on a number of wavelengths, began at 1630 hours, UT. No solar flare could be seen on the sun's disk, although a prominent flare would normally be apparent at the time of the radio disturbance. It now appears that the reason for this anomaly can only be conjectured until solar behavior is known in much greater detail than at present.

The understanding of the association between solar events, ionospheric disturbances, and geomagnetic storms has played an important part in the Bureau's radio propagation prediction services, particularly in the radio disturbance warning network. Part of this prediction work, based on the analysis and evaluation of solar radio data received from many sources, is the determination of the relationships between various solar events, radio fadeout, and temporary changes in the earth's magnetic field. The unusual solar event of June 9, completely at variance with the experience of many years, has caused the Bureau to question the validity of some of what were considered to be established relationships.

As soon as the severity of the blackout of June 9 became apparent, radio and optical observations were intensified. The initial position of the radio-burst source on the sun's disk was established, by high resolution scan at 10.7 cm, to be N 24, E 90.[1] In the light of the H-alpha (α) spectral line, only jets and bright loops were observed at this position. It was not until almost 1½ hr after the first event that the expected Hα flare became observable at N 19, E 90. Ordinarily, the flare is seen at the same time as the radio disturbance is observed.



Cross section of the sun, from above, during the unusual solar event of June 9, 1959. An extremely severe radio blackout of long duration occurred without the expected coincident solar flare.

Complete blackout of the Bureau's radio station, WWV, occurred at a number of receiving locations. Cosmic noise absorption of an outstanding nature (3+) was evidenced by the great drop-off in received signal strength, and also by the unusually slow onset of the absorption. Solar radio bursts at 18 Mc/s were classified as 3+ in importance, and bursts at high frequencies (4.3 mm, 10.7 cm) were very strong. These observations classify the ionospheric events as of relatively great importance (3+).

Past observations of such outstanding events have, in almost all cases, revealed the presence of an Hα flare of major importance. The absence of such a flare in itself establishes the June 9 event as a most unusual one. This anomaly raises a number of serious problems concerning the understanding of solar-terrestrial relationships.

Both of the Hα jet ejections that took place appeared to be based on the back side of the sun. The jet phenomenon, together with unusually late appearance of the flare itself, lead to the speculation that an early stage of the flare itself also occurred on the back side of the sun and in closer time-association with the earlier events mentioned. There is, of course, no way of establishing the "back-side" flare as a fact.

Assuming such a "back-side" flare presents still another problem: Ascertaining how the solar radio emission, and the ionizing emission which produced the radio fadeout, could have reached the earth if they were generated in the same solar region as the unobservable Hα flare. Normally, both emissions, Hα and ionizing radiation, travel in essentially straight lines. For these emissions to come from the same source, it would be necessary to assume a different trajectory for the back-side Hα emission than for the ionizing radiation, a conclusion at variance with many prior observations. However, it may be inferred that the Hα flare originated at a lower level in the sun's atmosphere than the source of the emissions. This inference would help explain why the Hα flare was not observed, although the ionizing radiation was able to reach the earth.

Another unusual feature of the events of June 9 was the exceptionally low velocity of the radio emission source. The velocity was deduced from observations at two separate low frequencies. Slow drift bursts on dynamic spectrum records

normally show velocities of the order of 1,000 km/sec at metric wavelengths.[2] By comparison, velocities derived from 18-, 38-, and 200-Mc/s fixed-frequency observations during the June 9 events average about 250 km/sec.

An additional complication, a point of great interest which is under current study, is the lack of subsequent major geomagnetic and ionospheric storms. The earth's magnetic field registered no major disturbance in the following few days.[3] Under ordinary circumstances, such disturbances would be expected.

This fact, coupled with the other apparent anomalies in the solar event of June 9, has forced a critical reappraisal of past techniques of observation and earlier conclusions from data. The resulting inquiry can be expected to lead to increased understanding of the relationships between the individual components of associated solar events, and a consequent improvement in radio propagation prediction methods.

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[1] The 4.3-mm and 10.7-cm outbursts of June 9, 1959, *by J. R. Coates, A. E. Covington and S. Edelson; paper presented at the 103d meeting of the American Astronomical Society, University of Toronto, 1959.*

[2] The radio spectrum of solar activity, *by A. Maxwell, G. Swarup and A. R. Thompson; Proc. IRE. Radio Astronomy Issue* **46(I)**, 142 (1958).

[3] *There was a sudden commencement on June 11, followed by moderately disturbed three-hour K figures: 5, 6, and 5.*

Solar Events, June 9, 1959

TIME TABLE

Cosmic Noise Absorption, importance 3+; unusually gradual onset, and very deep absorption. Start 1638 UT.

Shortwave Fadeout, importance 3+. Start 1635 UT.

Radio Bursts

$\lambda = 4.3$ *mm*
Outburst, start 1652 UT.

$\lambda = 10.7$ *cm*
Outburst, start 1728, Max. 1740 UT. Peak flux 2,000 (10^{-22} w/m^2/c/s), followed by post-burst increase; duration 6 hr 20 min.
Group of bursts, start 1707 UT.
Outbursts, start 1728, Max. 1740 UT. Peak flux 1,800 (10^{-22} w/m^2/c/s), accompanied by bright Hα jet.

$\lambda = 1.5m$ (*200 Mc/s*)
Major outburst with second part, start 1651 UT.

$\lambda = 8m$ (*38 Mc/s*)
Burst, start 1707 UT.

$\lambda = 17m$ (*18 Mc/s*)
Burst, start 1735 UT.

Hα Flare, importance 2, at N 19, E 90, start before 1800 UT.

Organizational and Administrative Changes

IN RECENT months, many organizational changes have been made at both the Bureau's Washington and Boulder laboratories. The changes are designed to streamline the Bureau's operations in order to meet the continually changing and increasing needs of modern science and technology.

Washington Laboratories

At the Washington laboratories, a new division, Instrumentation, has been established. G. Franklin Montgomery is chief of the new division, which comprises three sections from the Electricity and Electronics Division (Engineering Electronics, Electron Devices, and Electronic Instrumentation), a part of the Mechanical Instruments Section from the Mechanics Division, and the Basic Instrumentation Section, which was formerly the NBS Office of Basic Instrumentation. Joshua Stern has been named chief of the Basic Instrumentation Section.

The Instrumentation Division will investigate the fundamental properties and limitations of instruments, of their components and materials, and of measuring, recording, and signal-processing methods; investigate basic phenomena that may be usefully applied to instrumentation; develop improved instrumental techniques, instruments, and devices; provide scientific information and advice on instrumentation to other divisions of the Bureau, other Government agencies, and the public;

develop specific instruments and systems for other divisions of the Bureau and, by special arrangement, for other Government agencies; and provide calibration and repair services in certain instrument matters not included in the activities of other Bureau divisions.

The remaining five sections of the old Electricity and Electronics Division (Resistance and Reactance, Electrochemistry, Electrical Instruments, Magnetic Measurements, and Dielectrics) now make up the Electricity Division, with Dr. C. H. Page as Chief.

The duties of the Electricity Division will include establishment, maintenance, and dissemination of units and standards for measurements in electricity and magnetism; determination of fundamental constants of nature; basic research in the nature of dielectric and magnetic matter; calibration of standards and precision instruments for industry; testing electrical apparatus and supplies purchased by the Government; furnishing consulting service to government agencies; and devising new types of electrical apparatus.

Another reorganized division, Metrology, has replaced the Optics and Metrology Division. A. G. McNish has been named chief of the new division, which contains all the sections of the old division (Photometry and Colorimetry, Refractometry, Photographic Research, Length, and Engineering Metrology), plus the Mass and Scale Section and the Volumetry and Densimetry Section from the Mechanics Division.

As it is now constituted, the Metrology Division will be in charge of establishment, maintenance, and dissemination of units and standards of length, mass, volume, light (including ultraviolet and infrared), and color; conducting research, devising test methods, and making calibrations to make these standards more available for government and public use; determination of fundamental properties of materials such as refractive index and thermal expansion; calibration and testing of length standards and gages; measurement of optical apparatus and materials, photographic materials, reference weights, volumetric, density, and fluid capacity measures; development of new types of optical and photometric apparatus for military purposes; preparing standards and specifications to promote the standardization and greater uniformity of screw threads and other products; and furnishing consulting service to other government agencies.

The Mechanics Division has one new section, Pressure and Vacuum, of which Dr. D. P. Johnson has been named chief.

In the Heat Division, one section, Thermodynamics, has been disbanded, and four new sections have been established. The new sections and their chiefs are: Heat Measurements, Dr. D. C. Ginnings; Equation of State, Joseph Hilsenrath; Statistical Physics, Dr. M. S. Green; and Molecular Spectroscopy, Dr. D. E. Mann.

Dr. Alan D. Franklin has been named chief of the Mineral Products Division. He had been Acting Chief since November 1959, when he succeeded Dr. Irl C. Schoonover, now the Bureau's Associate Director for Planning.

In other appointments, Dr. Ugo Fano and William A. Wildhack have been named Special Assistants to the Director and Dr. K. E. Shuler has been named consultant to the Director. Dr. Fano, while continuing his own research, will serve as consultant on the theoretical aspects of the Bureau's program. He will further collaboration and interchange among those concerned with theoretical research, and will suggest means of enhancing their work, both as individuals and as a group. Mr. Wildhack will keep the Director informed of the needs of industry and other government agencies for precision standards, calibration services, and measurement techniques—particularly those which require extension of NBS capabilities. Dr. Shuler will advise the Director on matters connected with strengthening the scientific program at NBS. He will continue to undertake theoretical research in chemical physics.

Biographical Sketches

G. Franklin Montgomery, *Chief, Instrumentation Division*—formerly chief of Electronic Instrumentation Section; born 1921 in Oakmont, Pa.; BS in Electrical Engineering, Purdue University, 1941; joined NBS in 1946.

Joshua Stern, *Chief, Basic Instrumentation Section*—formerly with NBS Office of Basic Instrumentation; born in New York City in 1916; BS in chemistry, College of the City of New York, 1935; joined NBS in 1951.

Dr. Chester H. Page, *Chief, Electricity Division*—formerly Consultant to the Director and Acting Chief, Electricity and Electronics Division; born Providence, R.I. in 1912; AB, ScM, Brown University, 1934; PhD Yale University, 1937; joined NBS in 1941.

Alvin G. McNish, *Chief, Metrology Division*—formerly Consultant to the Director and Acting Chief, Optics and Metrology Division; born Washington, D.C., in 1903; AB George Washington University, 1924; MS 1931; joined NBS in 1946.

Dr. Daniel P. Johnson, *Chief, Pressure and Vacuum Section*—formerly Acting Chief, Mechanical Instruments Section; born in Lindsborg, Kansas in 1910; BS in chemistry, McPherson College, 1930; MA in physics and astronomy, Kansas University, 1933; PhD in physics, University of Wisconsin, 1939; joined NBS in 1935.

Dr. D. C. Ginnings, *Chief, Heat Measurements Section*—formerly with Thermodynamics Section; born 1905 in Kirksville, Mo.; BS in chemistry, University of Illinois, 1926; MS 1927; joined NBS in 1929.

Joseph Hilsenrath, *Chief, Equation of State Section*—formerly with the Thermodynamics Section; born 1912 in Tarnapol, Poland; AB New Jersey State Teachers College, 1937; MA Montclair (N.J.) State Teachers College, 1940; BS Renssalaer Polytechnic Institute, 1946; joined NBS in 1948.

Dr. M. S. Green, *Chief, Statistical Physics Section*—formerly with the Thermodynamics Section; born 1922 in Jamaica, New York; BA Columbia University, 1944; MA Princeton University, 1947; PhD 1951; joined NBS in 1951.

Dr. D. E. Mann, *Chief, Molecular Spectroscopy Section*—formerly with the Thermodynamics Section; born 1924 in New York City; PhD in chemistry, University of Chicago, 1948; joined NBS in 1954.

Dr. Alan D. Franklin, *Chief, Mineral Products Division*—formerly Acting Chief of the Division; born in 1922 in Glenside, Pa.; BA in chemistry, Princeton University, 1946; PhD 1950; joined NBS in 1955.

Dr. Ugo Fano, *Special Research Assistant to the Director*—formerly Chief, Radiation Theory Section; born 1912 in Torino, Italy; DSc in mathematics, University of Torino, 1934; joined NBS in 1946.

William A. Wildhack, *Special Assistant to the Director*—formerly Chief, Office of Basic Instrumentation; born 1908 in Breckenridge, Colorado; BS University of Colorado, 1931; MS 1932; joined NBS in 1935.

Dr. K. E. Shuler, *Consultant to the Director*—formerly consultant to the chief of the Heat Division; born 1922 in Nüremburg, Germany; BS Georgia Institute of Technology, 1942; PhD in physical chemistry, Catholic University, 1949; joined NBS in 1955.

Boulder Laboratories

The Boulder Laboratories have also undergone several recent changes in organization. In the Central Radio Propagation Laboratory (CRPL) the ever increasing emphasis on outer space research has necessitated the creation of the Upper Atmosphere and Space Physics Division, headed by Dr. C. G. Little. He will be assisted by Dr. D. M. Gates, who will also head the Atmospheric Spectroscopy group within the Division. This division will conduct basic and applied research in the physical and dynamic properties of the earth's upper atmosphere and the interplanetary medium; the interactions of electromagnetic and corpuscular radiation with both media; the influence of the sun upon these media; comparative studies of the earth's atmosphere with the atmosphere of other planets; and laboratory studies of ionized gases and atmospheric constituents with reference to solar and planetary atmospheres and the interplanetary medium.

Formation of the new division involved subdividing the Radio Propagation Physics and the Radio Communication and Systems Divisions. Four sections of the Radio Propagation Physics Division (Upper Atmosphere and Plasma Physics, Ionosphere and Exosphere Scatter, Airglow and Aurora, and Ionosphere Radio Astronomy) were transferred to the new division.

As a result of these changes, the Radio Propagation Physics Division has been renamed Ionosphere Research and Propagation, with Dr. E. K. Smith as Division Chief, and T. N. Gautier as Assistant Chief. It will act as the primary agency for the conduct and coordination of basic research on the propagation of radio waves as affected by the ionosphere, and on the special factors which can give rise to large departures from the normal behavior; conduct basis research on the nature of the media through which these radio waves are transmitted and the interaction of radio waves with the media; prepare predictions of radio wave propagation and warnings of disturbances; act as a central repository for data, reports, and information in the field of ionospheric radio wave propagation; and maintain a staff of experts on the characteristics of the ionosphere, and on radio wave propagation in it, for consultation when needed by other government agencies and industries.

Two newly appointed section chiefs in CRPL are Dr. Kenneth Davies in the Ionosphere Research Section of the Ionosphere Research and Propagation Division, and R. S. Lawrence in the Ionospheric Radio Astronomy Section of the new Upper Atmosphere and Space Physics Division.

Two new sections have been added to the Radio Standards Laboratory, now headed by Dr. J. M. Richardson. The general function of the Atomic Frequency and Time Standards section, Dr. R. C. Mockler, Chief, will be to conduct fundamental research and development that will lead to the creation, improvement, and applications of national standards of frequency and time intervals, having accuracies to meet existing or anticipated needs. This work includes: custody, maintenance, evaluation, and improvement of the national standards of frequency and time interval; research in the fundamental aspects of frequency and time interval measurements; basic studies of atomic and molecular frequency devices, high resolution spectroscopy, and the frequency control properties of materials; and experiments of physical significance which apply the techniques developed for frequency and time standards.

The Millimeter Wave Research Section, Dr. W. Culshaw, Chief, will perform the following functions: research on the generation, detection, transmission, and measuring of millimeter and submillimeter wavelengths; the application of the results of this research to millimeter wave interferometry, atomic and molecular spectros-

copy including maser research, plasma investigations, lengths and other standards, and the determination of physical constants, such as the velocity of light.

Dr. J. J. Sopka has been designated leader for the newly formed Math-Analysis and Computation Facility Group. Members of this group will be responsible for research and consultation for the Boulder Laboratories in mathematical analysis and computation procedures. They will also conduct studies in pure and applied mathematics in support of the laboratories' research programs, provide professional, experienced competence in large-scale computer and numerical analysis procedures, and assume responsibility for an optimal large-scale computer and data processing facility and its operation.

Alan H. Shapley has been appointed Chief of Liaison and Program Development for the Central Radio Propagation Laboratory. Mr. Shapley will have primary responsibility for maintaining an effective relationship between CRPL and the various national and international societies and committees whose activities influence programs of CRPL, and for advising the Director on program emphasis as influenced by those activities.

Edmund H. Brown has been assigned as Consultant in Mathematical Physics and Educational Director. He will act as consultant in basic research in mathematical physics and its applications to cryogenics, thermodynamics, ionosphere physics, etc. He directs the educational and formal training programs at the Boulder Laboratories, serves as permanent chairman of the Education Committee, and, as Director of the Graduate School.

E. F. Florman has been assigned as Consultant for the Radio Propagation Engineering Division.

Biographical Sketches

Dr. C. Gordon Little, *Chief, Upper Atmosphere and Space Physics Division*—formerly Chief of the Radio Astronomy and Arctic Propagation Section; born in Liu Yang, Hunan Province, China, in 1924; BS in physics, University of Manchester, England, 1948; PhD in radio astronomy, 1952; joined NBS in 1958.

Dr. David M. Gates, *Assistant Chief, Upper Atmosphere and Space Physics Division, and head of the Atmospheric Spectroscopy Group*—formerly Assistant Chief, Radio Propagation Physics Division; born in Manhattan, Kansas in 1921; BS, University of Michigan, 1942; MS 1944; PhD in physics 1948; joined NBS in 1957.

Dr. Ernest K. Smith, *Chief Ionosphere Research and Propagation Division*—formerly Chief of the Ionospheric Research Section; born in Peking, China in 1922; AB in physics, Swarthmore College, 1944; MS Cornell University, 1951; PhD 1956; joined NBS in 1951.

Thomas N. Gautier, *Assistant Chief, Ionosphere Research and Propagation Division*—formerly Consultant to this Division; born in Miami, Florida in 1913; BS, University of Florida, 1936; MS 1939; joined NBS in 1942.

Dr. Kenneth Davies, *Chief, Ionosphere Research Section*—formerly a senior physicist in the Ionosphere Research Section; born in Merthyr Tydful, Wales, in 1928; BS in physics, University of Wales, 1950; PhD 1953; joined NBS in 1958.

Robert S. Lawrence, *Chief, Ionospheric Radio Astronomy Section*—formerly project leader in the Radio Astronomy and Arctic Propagation Section; born in Worcester, Mass., in 1925; BS in physics, Worcester Polytechnic Institute, 1949; MS, Yale University, 1950; joined NBS in 1948.

Dr. John M. Richardson, *Chief, Radio Standards Laboratory*—formerly Chief of the Gaseous Physics Group; born in Rock Island, Ill., in 1921; AB in physics, University of Colorado, 1942; MA, Harvard University, 1947; PhD 1951; joined NBS in 1952.

Dr. Richard C. Mockler, *Chief, Atomic Frequency and Time Standards Section*—formerly on staff of the Radio Standards Division; born in Middletown, Ohio in 1925; BS in chemistry, Northwestern University, 1948; MS, University of Chicago, 1951; PhD in physics, Duke University, 1954; joined NBS in 1954.

Dr. William Culshaw, *Chief, Millimeter-Wave Research Section*—formerly on staff of Radio Standards Division; born in Lancashire, England in 1914; BS in physics, University of Sheffield, 1941; BS in mathematics, University of London, 1947; PhD in physics, 1952; joined NBS in 1956.

Dr. John J. Sopka, Jr., *Leader, Math-Analysis and Computation Facility Group*—formerly Mathematical Consultant to the Director; born in Elizabeth, New Jersey in 1919; BS in mathematical physics, Harvard University, 1942; MA in mathematics, 1946; PhD 1950; joined NBS in 1959.

Alan H. Shapley, *Chief, Liaison and Program Development for the Central Radio Propagation Laboratory*—formerly Assistant Chief of the Radio Propagation Physics Division; born in Pasadena, Calif., in 1919; AB in geophysics, Harvard University, 1940; joined NBS in 1947.

Edmund H. Brown, *Consultant in Mathematical Physics and Educational Director*—formerly a senior physicist in the Cryogenic Engineering Laboratory; born in Boston, Mass., in 1920; BS in engineering physics, University of Colorado, 1955; joined NBS in 1952.

Edwin F. Florman, *Consultant, Radio Propagation Engineering Division*—born in Venice, Illinois in 1904; MS, Washington University (St. Louis), 1934; rejoined NBS in 1946, having previously been with the Bureau from 1941–44.

NBS Scientific Divisions

Washington

Electricity Division*—Dr. C. H. Page*
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